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Does EU Emissions Trading Bite? An Event Study¹

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Abstract

The aim of this paper is to examine whether shareholders consider the EU Emissions Trading Scheme (EU ETS) as value-relevant for the participating firms. An analysis is conducted of the share prices changes as caused by the first publication of compliance data in April, 2006, which disclosed an over-allocation of emission allowances. Through an event study, it is shown that share prices actually increased as a result of the allowance price drop when firms have a lower carbon-intensity of production and larger allowance holdings. There was no significant value impact from firms' allowance trade activity or from the pass-through of carbon-related production costs (carbon leakage). The conclusion is that the EU ETS does 'bite'. The main impact on the share prices of firms arises from their carbon-intensity of production. The EU ETS is thus valued as a restriction on pollution.

Keywords: EU ETS; allowance transactions; carbon trading; over-allocation; event study.

1. Introduction

To meet its greenhouse gas emission targets, the European Union (EU) has introduced in 2005 the EU Emissions Trading Scheme (EU ETS).² This scheme is based on “cap-and-trade” regulation. The total amount of emissions is ‘capped’ and the EU emission allowances, which make up the subsets of that total amount, are tradable. In Phase I (2005-2007) and Phase II (2008-2012) of the EU ETS, the total domestic supply of allowances was determined through National Allocation Plans (NAP). However, at the end of April, 2006, the first EU Member State annual reports were published. These reports showed that national demand for allowances in 2005 was much less than supply. The resulting carbon price drop was the main signal that market participants revised their expectations on the shortage of allowances.

But while supply was larger than demand, the carbon price did not immediately fall to zero. And while one can expect investors to put a lower valuation on cleaner rather than dirtier firms, the statistics (to be shown later) suggest that dirtier firms instead received a lower valuation. Yet, if the carbon price drop lowers firms’ valuations, it does not suggest that the EU ETS is costly. Since share prices reflect the firms’ *future* profitability, the EU ETS ‘bite’ is in the market’s expectation of its *future* related costs. The aim of this paper is to find out whether investors consider the EU ETS as relevant for polluting firms, and how this is related to the firms’ allowance allocations and transactions.

The central question of this paper is therefore: Did EU ETS firms’ shareholders interpret the April 2006 carbon price drop as significant and, if so, how did the event’s impact differ among firms’ allocations and transactions?

This paper is organized as follows. In Section 2, the literature will be reviewed on the EU ETS how the impact of the EU ETS differs through the related allocations and transactions. In Section 3, hypotheses are formulated on the share price responsiveness

through which the carbon price drop impacted the EU ETS firms. The methodology will be discussed in Section 4. The empirical results and a discussion thereof will be presented in Sections 5. Section 6 concludes the paper.

2. Literature review

With an abundant supply of allowances one may expect the regulation did not affect the firms' management or share prices. For example, Anger and Oberndorfer (2008) showed for a sample of German firms that allocations did not impact revenues and employment. Kettner et al. (2008) concluded it was unlikely that abatement had taken place.

However, ex-post research shows the EU ETS did have an impact on firms. Anderson and Di Maria (2011) showed there were both 'under-allocations' as well as 'over-allocations' and that some firms did reduce emissions. Abrell et al. (2011) found that the profit margins of over-allocated firms were positively affected, *et vice versa*. Furthermore, the market valuations of firms were responsive to the carbon price. For example, Oestreich and Tsiakas (2012) analyse the "carbon premium", defined as the share price return difference of dirty versus clean firms. They find that this premium is higher for dirtier firms. However, when focusing on energy companies in the EU, Koch and Bassen (2013) find the opposite, namely that dirtier firms have higher costs of capital due to carbon related risks and thus a lower equity value. Moreover, through an event study on the April 2006 carbon price drop, Bushnell et al. (2013) shows that the market values of dirtier *non-energy* industries declined more, i.e. dirtier firms were more heavily penalized, as was found for the *energy* industry in Koch and Bassen (2013).³ Among energy firms, however, the impact was the opposite, i.e. being cleaner will be penalized, as with Oestreich and Tsiakas (2012).

This study contributes to the literature through the inclusion of the firms' allowance purchases and sales from the EU ETS database: the European Union Transaction Log

(EUTL). Only three studies have analysed these EU ETS transactions. Both Jaraitė and Kažukauskas (2012) and Zaklan (2013) examine determinants in purchasing and selling allowances. Yet, to our knowledge the impact of these transactions on share prices has not been analysed yet.

Bushnell et al. (2013) also conduct an event study on the same allowance price fall in the EU ETS. However, our paper is different from theirs. First, where Bushnell et al. (2013) make an industry comparison by focusing on power versus non-power industries, we use a more specific categorization of industries to test the effect of the allowance price fall on share prices. Second, contrary to Bushnell et al. (2013) we bring the buying and selling of allowances, which is the very essence of emissions trading, into the analysis, by incorporating such purchases and sales into a number of hypotheses. Third, as a result our conclusions partly reproduce but also partly differ from theirs, which enhances the validity of both studies and adds new insights to this carbon market event.

The literature thus shows that the ex-post results are mixed on the impacts of over-allocation and of carbon-intensive production, and that there is a literature gap regarding the effects of allowance trade on share prices. This paper fills these gaps by incorporating allowance trade with the allocation and the product market in determining the EU ETS impact on share prices. In the next section hypotheses are formulated on the interplay of these three factors.

3. Theoretical framework and hypotheses

Several related effects on firms' market values occur simultaneously with a change in the carbon price. The three main effects, discussed below, are: (1) carbon leakage and carbon-intensity effects, (2) exposure and borrowing effects, and (3) trade effects.

3.1 Carbon leakage and carbon-intensity effects

Carbon-intensive production becomes less attractive in an emissions trading scheme. ‘Carbon leakage’ refers to the consequential relocation of companies, and thus emissions, to countries where restrictions on carbon emissions are weaker. Firms competing with firms from outside the system cannot or can partly pass on carbon-related costs in their product prices. This decreases their profit margins. Once the carbon price drops, the profit margins and thus share prices should increase of firms within the EU ETS. The first hypothesis H.1 is therefore:

Market values of firms with carbon leakage increase. Increases are larger for dirtier firms, i.e. with a higher carbon-intensity of production, than for cleaner firms. (H.1)

Hence, if firms can pass-through less than 100% of their carbon-related costs, a drop in the carbon price increases the market value of such firms.

However, if firms can pass on at least 100%, i.e. they do not suffer from carbon leakage, the carbon price drop decreases product revenues, profits and thus their market values.⁴ Indeed, Oberndorfer (2009) finds a positive share-price-to-carbon-price relationship for European power firms. The carbon cost margin, i.e. the carbon price times the emissions per unit of production, is higher for firms with a dirtier production. Product prices of dirtier firms will thus decrease more when the carbon price drops, lowering their profits and thus their share prices. Contrary to H.1, the impact for dirty versus clean firms is thus the opposite. As a result, the second hypothesis H.2 is that:

Market values of firms without carbon leakage decrease.

Decreases are larger for dirtier firms than for cleaner firms. (H.2)

3.2 Exposure and borrowing effects

Polluting firms in the EU ETS either receive their allowances for free or they have to buy them at auction. Auctioning or free allocation have similar economic costs (costs of buying allowances or the opportunity costs of using free allowances) but do effect accounting profits and the market values of firms differently. Firms receiving free allowances should thus have higher market values than comparable firms having to buy them at auction. Typically, the former is long on allowances, while the latter is short. The carbon price drop should thus have lowered the cost burden for firms that were short on allowances on an annual basis. The hypothesis is that investors see the accumulation of these lowered cost burdens into increases in market values. The third hypothesis is thus as follows:

Market values increase the more firms are short on allowances.

Market values decrease the more firms are long on allowances. (H.3)

However, in the short-term the price drop decreases the value of allowances held in stock. This negatively affects the market values of firms. One of the features of the EU ETS Directives (2003/87/EC and 2009/29/EC) allowing firms to manage short-term impacts is called ‘borrowing’. In the EU ETS, firms receive their next year’s allocation of allowances prior to the compliance date for their current year’s emissions. Firms can thus ‘borrow’ these allowances to cover for their current year’s emissions. But in case firms foresaw the carbon price drop they should *also* have sold any of their remaining allocation holdings. As such a strategy is a signal of market insight, firms with lower net stock positions should have higher market values. The fourth hypothesis is then as follows:

Market values increase the more firms decreased their net stock holdings by borrowing and selling allowances. (H.4)

3.3 Trade effects

If rational expectations are assumed, firms should trade for any discrepancies between allocations and emissions. However, firms do not only trade to eliminate these mismatches, they may also actively bet on carbon market developments. Active traders might know more about the workings of the market and thus have an information advantage. Investors might therefore positively value firms active at trading allowances, irrespective of whether they are buying or selling. The last hypothesis is thus as follows:

Market values increase the larger the firms' shares in the allowance trade. (H.5)

4. Methodology

4.1 Abnormal share returns

In order to estimate the market valuation effects around the carbon price shock, we use an event study. This approach was introduced by Fama et al. (1969) initially for corporate finance purposes, but has also been applied within the field of regulatory economics.

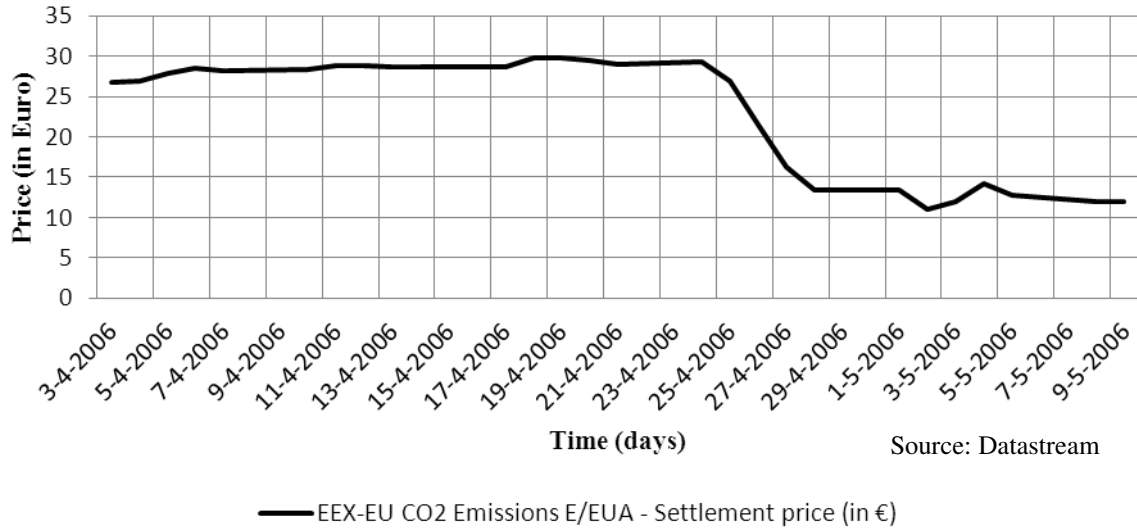
The event study methodology implicitly assumes the market is efficient: all available information impacting future profits of firms is discounted into the share prices. If an event is significant for a firm it should thus be possible to extract from its share price the firm-specific returns associated with the event.⁵ Subsequently, these “abnormal returns” can be analysed by relating them to these firm's characteristics. Here the firms' industry categories, revenues, allocations, emissions, and allowance purchases and sales will be considered.

For obtaining the market returns the Return Index (RI) was used from Datastream.⁶ With RI the returns $r_{i,t}$ can be calculated by first-differencing its natural logarithm:

$$r_{i,t} \equiv \log(1+RI_{i,t}) = \ln(RI_{i,t+1} / RI_{i,t}) = \ln(RI_{i,t+1}) - \ln(RI_{i,t}) \quad (1)$$

where i stands for the company $i = 1, \dots, N$ and $i = m$ denotes the market index. These market portfolio returns $r_{m,t}$ are proxied by the *RI* of the Morgan Stanley Capital International EU equity market index. The subscript t stands for the trading day.

Figure 1: EU Allowance unit settlement price around the 25th of April, 2006 (in €)



As Figure 1 shows, the start of the event window is to be pinpointed at the 24th as it is the last day the price moved upwards. And since the price fall took off from the 25th we consider it the day of the event, i.e. for which $t = 0$.⁷ The inclusion of the 24th, i.e. for which $t = -1$, allows for the effects of prior information on the share prices. The event window should not encompass too many days as that may affect the degree of bias of the statistical analysis, but with too few days the impact of the event may not be captured (e.g. Campbell et al., 1997). We therefore devise three event windows: one with the 26th of April ($t_1 = \{-1, 1\}$), one with the 27th ($t_2 = \{-1, 2\}$), and one with the 28th ($t_3 = \{-1, 3\}$).⁸

In order to estimate the “abnormal” returns caused by the event a business-as-usual estimate is needed. This estimate was determined by running, for each firm, an Ordinary Least Squares (OLS) regression:

$$r_{i,t} = \alpha_i + \beta_i r_{m,t} + u_{i,t} \quad (2)$$

These OLS regressions are run in a sufficiently large time period of 60 days *before* the event, the estimation window.⁹ The next step is to plug the *estimation* window intercepts ($\hat{\alpha}_i$) and beta's ($\hat{\beta}_i$), and the *event* window's realized firm ($r_{i,t}$) and market returns ($r_{m,t}$) into equation (3):

$$r_{i,t} = \hat{\alpha}_i + \hat{\beta}_i r_{m,t} + \varepsilon_{i,t} \quad (3)$$

The error term $\varepsilon_{i,t}$ represents the abnormal returns ($AR_{i,t}$). It is standard to aggregate these returns over the event window. Since if these returns are *significantly* affected during the event window, they will not revolve around zero but maintain a new level. For t_1 , for example, these cumulative abnormal returns (CAR) can be calculated by summing $AR_{i,t}$ from $t = -1$ to $t = 1$.

4.2 Carbon leakage and carbon-intensity effects

For the carbon leakage estimate we draw on three Commission decisions (European Commission, 2010; 2011; 2012). These include lists of product categories deemed exposed to 'carbon leakage'. As these product categories are provided in NACE codes, a dummy variable $carbleak_i$ is defined equaling 1 if a firm's NACE code appears in the three Commission Decisions' lists.

The carbon-intensity of production (called: $carbintens_i$) is estimated as follows^{10,11}:

$$carbintens_{i,2005} = emissions_{i,2005} / revenues_{i,2005} * 100\% \quad (4)$$

The effect of carbon-intensity on share prices depends whether a firm suffers from carbon leakage. We take care of this interaction via a variable $carbileak_i$, the product of $carbintens_i$ and $carbleak_i$.

Hypothesis H.1 suggests that with carbon leakage, share prices of dirtier firms increase more than those of cleaner firms. H.1 will then be accepted if $carbleak_i$ and $carbileak_i$ are positively related to CAR_i . To accept H.2, the opposite should hold.

4.3 Exposure and borrowing effects

Regarding the value effects associated with allocations and emissions two effects are important: 1) an exposure valuation: the allocations minus emissions amounts to come, and 2) a stock valuation: the value of allowances firms currently have in stock. As to the exposure valuation, it is expected that investors see annual shortfalls or surpluses in relative terms. One thus only needs to take the difference between allocations and verified emissions and divide it by either of the two. But for a part of the allowance transactions, it could not be discerned whether allocations belonged to the 2005 or 2006 tranches. The sum of the two allocations was therefore taken, resulting in the following exposure variable:

$$exp_i = \frac{allocation_{i,2005} + allocation_{i,2006} - 2 * emissions_{i,2005}}{allocation_{i,2005} + allocation_{i,2006}} * 100\% \quad (5)$$

where $emissions_{i,2005}$ are multiplied by two given the two allocation tranches.¹² Hypothesis H.3 suggests market values increase (decrease) the more firms are short (long) on allowances. H.3 will then be accepted if exp_i is negatively related to CAR_i .

For the stock valuation effect, we devised a net holding estimate which takes into account 1) the possibility for firms to borrow, and 2) the net allowances sales – since, at higher pre-event carbon prices, it would have been profitable if firms had also sold their 2006 allocations. The reference date for the net holdings is set at the 30th of April, 2006, when allowances ought to be handed in. The net holding is then defined as:

$$borrow_i = \frac{emissions_{i,2005} + \sum_{2005}^{Apr 2006} sales_i - \sum_{2005}^{Apr 2006} purchases_i}{allocation_{i,2005} + allocation_{i,2006}} * 100\% \quad (6)$$

Hypothesis H.4 suggests market values increase the more firms decreased their stock holdings. For H.4 to be accepted $borrow_i$ needs to be positively related to CAR_i .

4.4 Trade effects

Investors may value firms that are active at trading allowances, irrespective of whether they are buying or selling. The estimate we adopted is the trade-intensity (called: $tradeintens_i$)¹³:

$$tradeintens_i = \frac{\sum_{2005}^{Apr2006} purchases_i + \sum_{2005}^{Apr2006} sales_i}{\sum_{i=1}^N (\sum_{2005}^{Apr2006} purchases_i + \sum_{2005}^{Apr2006} sales_i)} * 100\% \quad (7)$$

In addition, a dummy variable $notrade_i$ is defined equaling 1 for firms which had nor purchases nor sales, and zero otherwise.

Hypothesis H.5 suggests market values increase the larger the firms' shares in the allowance trade. For H.5 to be accepted $tradeintens_i$ needs to be positively related to CAR_i .

5. Results and discussion

5.1 Firm and industry selection criteria

By labeling with the Bureau van Dijk's (BvD) Orbis database codes, we identified 10,419 of 10,650 installations operators from the National Allocation Plans (NAP), and 5,737 of the 5,957 European Transaction Log (EUTL) accountholders which appeared in the 2005-2006 transactions. The majority of the installations' operator names were provided through overviews on the EU ETS website. The BvD-labelling of the remaining installations or EUTL transaction accounts was possible with other provided details, such as the names of the installations or accountholders themselves. Moreover, there are 25,020 transactions between the first transaction and the last one on the 30th of April, 2006. 898 of them are conducted among the same accountholders, e.g. for moving allowances from one national registry to

another, 9,664 are allocations and 4,743 are surrendered allowances. The inter-account trade data is thus based on the remaining 9,715 transactions.

The only common identifier in the NAPs and the EUTL transactions were the accountholder names. For most accountholder names in the NAPs, the received and surrendered allowances could be traced in the transactions. NAP accountholders that did not appear in the transactions before end December, 2006, were not included in the analysis (776 accountholders controlling 1,073 installations). By not appearing in allowance transactions, we considered these accounts must have opted out from the EU ETS. The main allocations and emissions source we opted for were the NAPs; unlike the EUTL transactions it provides the verified emissions.¹⁴ We complemented it with accounts which did not appear in the NAPs but according to the transactions received or surrendered allowances up until the 30th of April, 2006. We further included EUTL transaction accounts that were used for trading purposes only (and not for allowance allocations or surrenders).

The next step was to obtain the firms' International Security Identification Numbers (ISINs) or exchange-listing codes from Orbis. On the basis of the accountholder names and these listing codes, we merged the 2005-2006 allocations, emissions, and the cumulative purchases and sales until the 30th of April, 2006. Furthermore, firms were only selected if they took part in the EU ETS by having allocations and/or emissions, by having traded allowances, or both. For several firms data was unavailable in Datastream or Orbis on the share prices, revenues or total assets, decreasing the number of firms from 506 to 393. Table I shows the numbers of accountholders (and installations) divided over the listed and non-listed firms.

Table I: Sample of EU ETS accountholders

Number of accountholders	NAP-related	Non-NAP with allocations and/or surrenders	Only trade	Total
EU ETS total	6132	208	435	6775
01-01-2005 to 31-12-2006	(10,650 installations)			
Identified, in transactions, and firm-specific data is available:	2,167	99	191	2,457
01-01-2005 to 30-04-2006	(4,121 installations)			
- of which: listed firms	1,128	25	139	1,292
	(2424 installations)			
- of which: non-listed firms	1,039	74	52	1,165
	(1,697 installations)			

From the 2,167 identified accountholders, 1,128 (53%) and 1,039 (48%) are assigned to the listed and non-listed firms, respectively. From Orbis we obtained the firms' NACE Rev. 2 core codes. Based on the contents of the NACE code text descriptions, the NACE industries were checked whether they were among the European Commission's lists of carbon leakage industries, and they were categorized into the following ETS sectors: 1) Power & Heat, 2) Iron, Steel & Coke, 3) Cement & Lime, 4) Refineries, 5) Pulp & Paper, 6) Glass, 7) Ceramics, Bricks & Tiles, 8) Unidentified / Others.^{15,16,17}

5.2 Cumulative abnormal returns

The share prices, which determined the abnormal returns, are themselves established at the end of each trading day. These prices should thus reflect the carbon price changes on $t = 0$ for the initial decline and on $t = 1$ for the acceleration of the fall (cf. Figure 1).

Figure 2: Full sample average abnormal returns within event window $t = \{-2,3\}$

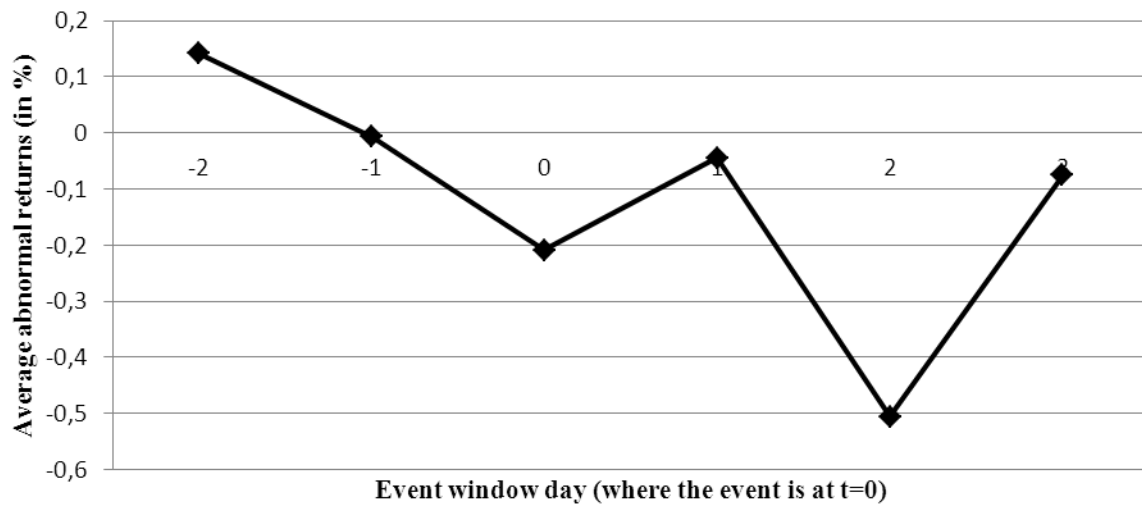


Figure 2 shows the path of the full sample average abnormal returns (ARs, not CARs) over an event window of $t = \{-2,3\}$. This event window illustrates that before and until $t = 0$, the abnormal returns gravitated to the negative. The initial and positive response to the news came at $t = 1$, suggesting investors belatedly realized the information had an impact on the firms' valuations. The market re-evaluated this shock (downwards) at $t = 2$. And it took another day for the ARs to tend back to zero, indicating the impact was not substantial overall. We thus expect event window $t_1 = \{-1,1\}$ to be informative as it includes the initial response to the news. Other event windows we consider are $t_2 = \{-1,2\}$ and $t_3 = \{-1,3\}$ which provide insights into the share price corrections the days after.

Table II shows the descriptive statistics for the CARs for the three event windows t_1 , t_2 , and t_3 .¹⁸ From t_1 to t_2 the average firm saw a decline in the mean of its CAR, but there was no average change from t_2 to t_3 .

Table II: Descriptive statistics on the CARs and on their significance

	Full sample	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6	Sector 7	Sector 8
CAR(-1,1)	N = 393	N = 25	N = 34	N = 13	N = 67	N = 34	N = 5	N = 4	N = 211
Mean	-0,25%	-0,90%	-0,31%	1,09%	-0,47%	-0,62%	-0,28%	1,88%	-0,16%
Std. dev.	2,91%	2,58%	3,99%	3,07%	2,98%	2,58%	2,03%	2,45%	2,78%
Median	-0,25%	-0,58%	-0,05%	0,62%	-0,45%	-0,30%	-0,72%	1,94%	-0,17%
Minimum	-13,07%	-6,99%	-13,07%	-2,14%	-8,42%	-6,98%	-2,31%	-1,14%	-11,55%
Maximum	11,91%	4,84%	8,20%	8,99%	9,92%	6,35%	2,96%	4,78%	11,91%
T-test	-1,71*	-1,74*	-0,45	1,28	-1,3	-1,41	-0,31	1,54	-0,82
SCAR test	-1,68*	-2,61***	-0,61	2,58***	-2,61***	-2,34**	0,43	2,88***	0,16
CAR(-1,2)									
Mean	-0,75%	-1,96%	-2,34%	0,39%	-1,16%	-1,22%	0,49%	1,60%	-0,29%
Std. dev.	4,11%	2,77%	4,30%	3,03%	3,72%	2,92%	3,28%	3,58%	4,48%
Median	-0,69%	-1,27%	-1,89%	-0,05%	-0,72%	-1,40%	-0,97%	2,00%	-0,34%
Minimum	-21,02%	-8,62%	-10,96%	-2,96%	-11,13%	-7,21%	-2,84%	-3,14%	-21,02%
Maximum	36,40%	2,36%	10,23%	8,71%	9,55%	7,04%	5,51%	5,54%	36,40%
T-test	-3,63***	-3,54***	-3,17***	0,46	-2,55**	-2,44**	0,33	0,9	-0,95
SCAR test	-6,97***	-6,07***	-6,04***	0,88	-5,2***	-4,37***	1,01	2,56**	-1,04
CAR(-1,3)									
Mean	-0,83%	-1,73%	-1,74%	0,32%	-1,51%	-1,10%	-0,29%	1,64%	-0,44%
Std. dev.	4,97%	3,37%	5,69%	3,53%	4,30%	4,43%	4,86%	2,76%	5,36%
Median	-0,86%	-1,18%	-2,03%	0,51%	-1,23%	-1,34%	-2,73%	1,62%	-0,47%
Minimum	-25,15%	-10,20%	-11,31%	-3,42%	-12,40%	-8,98%	-5,13%	-1,72%	-25,15%
Maximum	43,86%	3,04%	13,11%	8,84%	9,87%	12,31%	5,18%	5,05%	43,86%
T-test	-3,3***	-2,56**	-1,78*	0,32	-2,87***	-1,44	-0,13	1,19	-1,2
SCAR test	-7,85***	-5,21***	-5,07***	0,55	-7,05***	-3,89***	0,96	2,58***	-2**

For the significance of the CARs two types of test statistics are provided: the t-test and the standardized CAR (or: SCAR) test (cf. Campbell et al., 1997: section 4.4). The SCAR test weighs the CARs with the standard error of the estimation regression (cf. Section 4.1, equation 2). The corresponding p-values in Table II show that the (S)CARs are significantly different from zero.

If we consider t_1 , the SCAR test statistics point to significance of returns for five sectors. However, the mean CAR from the full sample is only significant at the 90% confidence level. As they are more significant for t_2 and t_3 , this lends support to include these days in the analysis. In t_2 and t_3 , four sectors had significant negative returns (sectors 1, 2, 4,

and 5), and one had small negative returns (sector 8).¹⁹ Hence, also from a sector perspective it is clear that the returns were negative in general.

Although the *CARs* seem small, the total value effect is substantial. Multiplying all firms' *CARs* with their average equity market values in April, 2006, yields a net value effect of € -54 billion for t_2 .²⁰ To put this figure into perspective, we can estimate the change in the opportunity costs of holding allowances by taking the carbon price drop over t_2 (€ 13,14) and multiplying it by the sum of the firms' two remaining allocations for Phase I.²¹ We find that these opportunity costs account for 1,22% of the firms' *total* April 2006 average equity market values, and 55,5% of the *change* in the April 2006 average equity market value as caused by the carbon price drop.

5.3 Carbon leakage and carbon-intensity effects

The first section of Table III shows the full sample statistics on carbon leakage and the carbon-intensity of production.²² The variable *carbintens*, or the amount of emissions per unit of revenues, has an average of 0,04%. This implies that, on average, there is one tonne of CO₂ emissions for every 25 Euro in revenues. The associated positive skewness of 6,55 indicates that there are few firms emitting many emissions per unit of revenues and that there are many firms with few emissions per unit of revenues. The mean of *carbleak* (55%) shows that the majority of firms is prone to carbon leakage.

Table III: Full sample descriptive statistics on the product market, exposure, borrowing, and allowance trading

Full sample	Mean	Std. dev.	Median	Min.	Max.	Skew.	N
<i>carbintens</i>	0,04%	0, 12%	0,003%	0%	1,23%	6,55	366
<i>carbleak</i>	55,22%	49,79%	100%	0%	100%	-0,21	393
<i>carbileak</i>	0,02%	0,06%	0%	0%	0,68%	6,65	366
<i>exp</i>	10,9%	54,86%	12,52%	-928%	100%	-13,44	377
<i>borrow</i>	-78,11%	2.285%	47,48%	-44.237%	232%	-19,3	377
<i>tradeintens</i>	0,25%	1,03%	0%	0%	9,53%	5,58	393
<i>notrade</i>	55%	0,5%	100%	0%	100%	-0,19	393

Table IV: Sector level descriptive statistics on the product market, exposure, borrowing, and allowance trading

Listed firms		Full sample N = 393	Sector 1 N = 25	Sector 2 N = 34	Sector 3 N = 13	Sector 4 N = 67	Sector 5 N = 34	Sector 6 N = 5	Sector 7 N = 4	Sector 8 N = 211
<i>N carbintens, where carbleak = 0</i>	A	157	22	1	3	11	3	0	0	117
	A	0,05%	0,28%	0,13%	0,03%	0,01%	0,003%	n.a.	n.a.	0,01%
<i>N carbintens, where carbleak = 1</i>	A	217	1	33	10	56	31	5	4	77
	A	0,03%	0,0001%	0,04%	0,19%	0,02%	0,04%	0,05%	0,05%	0,01%
<i>N carbintens</i>	A	366	23	33	12	67	32	5	4	190
	A	0,04%	0,26%	0,05%	0,15%	0,02%	0,04%	0,05%	0,05%	0,01%
	B	0,02%	0,16%	0,03%	0,09%	0,004%	0,01%	0,02%	0,004%	0,003%
<i>carbileak</i>	A	0,02%	5E-06%	0,04%	0,14%	0,02%	0,04%	0,05%	0,05%	0,002%
<i>N exp</i>	A	377	23	33	13	67	33	5	4	199
	A	10,90%	-1%	10,08%	15,22%	14,51%	24%	11,71%	13,70%	8,68%
	B	-0,99%	-13,92%	22%	9,16%	13,31%	24%	10,53%	21,61%	9,53%
<i>borrow</i>	A	-78,11%	65,40%	48,74%	45,54%	49,18%	51,24%	29,65%	50,05%	-193,40%
	B	48,37%	48,74%	54,91%	46,13%	49,68%	50,35%	-2,53%	49,59%	45,04%
<i>N tradeintens</i>	A	393	25	34	13	67	34	5	4	211
	A	0,25%	1,64%	0,19%	0,26%	0,07%	0,02%	0,58%	0,00%	0,19%
	B	100%	41,08%	6,59%	3,34%	4,36%	0,80%	2,89%	0,01%	40,93%
<i>notrade</i>	A	54,71%	20%	55,88%	38,46%	53,73%	47,06%	20%	50%	62,09%

Table IV provides for the variables a full sample average, sector averages (A) and a ‘sector ratio’ (B). The latter is calculated by considering each sector as being one ‘firm’. The allocations, surrenders, allowance purchases and sales are summed up per sector.

Both the sector average (A) and sector ratio (B) indicate that especially sector 1 (Power & Heat) but also sector 3 (Cement & Lime) emit most CO₂ per unit of revenue. Compared to the other sectors, their production is three to twenty-six times more carbon-intensive. However, sector 1 and sector 3 differ with respect to carbon leakage. In accordance with Hypothesis H.1, sector 3 with its high carbon leakage has positive *CARs* due to the carbon price drop. And sector 1 with no carbon leakage has negative *CARs*, which is in accordance with H.2. The outcomes of sectors 4, 5, and 8 are not in line with H.1 or H.2 since positive *CARs* were to be expected, given their carbon leakage.

Furthermore, Table IV shows that the average carbon-intensity is larger for firms without carbon leakage (0,05%) than for those with carbon leakage (0,03%). This is mainly due to the relatively high carbon-intensity of Sector 1 (0,28%). Without sector 1 the statistics point out that, when subject to carbon leakage, firms produce with a relatively higher carbon-intensity.

5.4 Exposure and borrowing effects

Table III further reports the descriptive statistics for the variables *exp* and *borrow*. It shows most firms were long on allowances; see the positive average and median values of *exp*.

The variable *borrow* is the ratio of the stock of allowances on the 30th of April, 2006, divided by the allocations of 2005 and 2006. The mean of -78% shows that the average firm expended and sold less allowances than it purchased. However, with 47,5% the median firm expended 95% of its 2005 allocation and banked the remainder plus the 2006 allocation. This implies a few firms skew the *borrow* variable towards a large negative mean, i.e. most firms were long in allowances.

That these surpluses were not subsequently sold off is an indication that many did not foresee the carbon price drop. On the other hand, the picture from *borrow* may be distorted. Our data only contains transactions from the spot market but not the derivatives market. Firms which purchased allowances on the spot market and sold them (at higher prices) through forwards and futures thus appear as not having foreseen the carbon price drop, while they actually may have profited from it via the derivatives market. This may be the case for three firms (Barclays PLC, AB Electrolux, and Severn Trent PLC) which had highly negative *borrow* values.²³

The sector perspective on *exp* and *borrow* is provided in the second section of Table IV. For most sectors the averages differ from their sector ratios, but the signs do not. The

result remains that all except sector 1 (Power & Heat) are long on allowances. Interestingly, the full sample average of 11% differs from the full sample sector ratio for the EU ETS of -1%. It implies that, on average, firms are long but on the whole the EU ETS is short. This number is close to the range of the EU ETS allocation estimations from Ellerman and Buchner (2008) and Anderson and Di Maria (2011). These were in the order of +0,6% and -0,5%, respectively. Hence, although the number is small, in aggregate the listed firms faced pressure to reduce their pollution.

The sector values for *borrow* are in accordance with those of Table III as values were in the 45-50% range. Only sectors 1, 5, and 7 borrowed from their 2006 allocations as their *borrow* rates were in the 50-100% range. For sector 1 it is to be expected to borrow given its shortfall in allowances. Sector 5 (Pulp & Paper), however, is long in allowances but the data show that pulp and paper firms used 51% of their two allocation tranches, either via covering their emissions or via net sales.

5.5 Trade effects

The last statistics in Table III are on the allowance trade. As the zero median of *tradeintens* indicates, most firms did not trade in allowances. The mean of *notrade* indicates this was the case for 55% of firms. Furthermore, the average firm's share of total EU ETS purchases and sales was 0,25%. The skewness of 5,58 indicates that a few firms conducted most of the trade in allowances.

The trade differences among industry sectors are provided in the last section of Table IV. The sector ratios of *tradeintens* show that most trade originates from sector 1 (Power & Heat) and 8 (Unidentified / Others) with, respectively, 41,1% and 40,9% of total allowance trade. The sector averages, though, indicate that the average firm in sectors 2, 3, and 6 traded

about as much or even more than the average firm within sector 8. Sectors 4, 5, and 7 were the least active.

5.6 Cross-sectional regression

In the OLS regressions the statistics point to a non-normal distribution of the residuals.²⁴ Normality of residuals, though, is not a sufficient condition for obtaining consistent estimates. In order to test whether the assumptions of the regression models are correct, Long and Trivedi (1992) suggests applying two types of specification tests: the robust LM Ramsey's RESET test and the Information Matrix (IM) test. If these tests are passed, the "interpretation of OLS estimates and application of standard statistical tests are justified" (Long and Trivedi, 1992).

There are five hypotheses to test over three event windows.²⁵ We group the variables in four blocks related to these hypotheses. Then we take up all significant variables in a subsequent regression. In Table V the OLS results with robust clustered standard errors are provided for the three windows.²⁶ The two specification tests do not point towards a misspecification of the estimated model.

A first inference one can make is that the fit of the model is weak, given the low (adjusted) R-squared. Yet, this is to be expected since the carbon price effect only indirectly relates to share prices. There can always be non-EU ETS related factors playing a role in determining the share price movements, e.g. changes in the macro-economic environment. And unlike the selected EU ETS variables, it may well be that the EU ETS impact on share prices manifests itself through other channels. For example, a firm's state of abatement technology and business strategy regarding climate change regulation, i.e. factors which are hardly measurable. Related to that, the carbon price shock may have changed investors' expectations on the EU ETS future stringency, and that the carbon price drop induced

Table V: OLS regressions on the CARs from event windows t_1 , t_2 , and t_3

	Event window t_1					Event window t_2					Event window t_3				
	H.1-H.2	H.3	H.4	H.5	H.1-H.5	H.1-H.2	H.3	H.4	H.5	H.1-H.5	H.1-H.2	H.3	H.4	H.5	H.1-H.5
<i>carbintens</i>	-1,649** (0,043)				-1,531** (0,022)	-3,782*** (0,0004)				-4,086** (0,017)	-1,339* (0,067)				-3,107 (0,251)
<i>carbleak</i>	-0,0003 (0,916)					-0,003 (0,187)					0,001 (0,711)				
<i>carbileak</i>	0,005 (0,997)					-1,831 (0,626)					-7,767 (0,161)				
<i>tradeintens</i>		-0,002* (0,08)			-0,0005 (0,52)		-0,003** (0,042)			-0,0003 (0,682)		-0,003* (0,082)			-0,0005 (0,761)
<i>notrade</i>		-0,006 (0,144)					-0,005 (0,377)					-0,008 (0,328)			
<i>exp</i>			1,64E-05* (0,099)		1,29E-05** (0,036)			1,56E-05 (0,128)					1,27E-05 (0,348)		
<i>borrow</i>				5,56E-08* (0,066)	-2,6E-08 (0,832)				-1,3E-07 (0,211)					-4,5E-07*** (0,001)	-5,2E-07 (0,123)
constant	-0,002 (0,421)	0,001 (0,72)	-0,002** (0,044)	-0,002* (0,051)	-0,002** (0,049)	-0,004 (0,164)	-0,004 (0,601)	-0,007* (0,072)	-0,007* (0,073)	-0,006* (0,072)	-0,007** (0,022)	-0,003 (0,637)	-0,008** (0,032)	-0,008** (0,029)	-0,007** (0,014)
R ²	0,005	0,011	0,001	0,000	0,006	0,019	0,008	0,0005	0,0001	0,016	0,014	0,007	0,0002	0,0005	0,007
Adjusted R ²	-0,003	0,006	-0,002	-0,003	-0,005	0,011	0,003	-0,002	-0,003	0,011	0,006	0,002	-0,002	-0,002	-0,001
AIC	-1541,85	-1663,88	-1596,2	-1595,85	-1540,14	-1318,08	-1391,07	-1358,92	-1358,77	-1319	-1177,94	-1242,5	-1215,56	-1215,65	-1175,28
N	366	393	377	377	366	366	393	377	377	366	366	393	377	377	366
F-test	0,110	0,192	0,099	0,066	0,044	0,001	0,008	0,128	0,211	0,005	0,010	0,188	0,348	0,001	0,002
RESET	0,292	0,151	0,157	0,355	0,297	0,496	0,163	0,668	0,426	0,501	0,136	0,197	0,607	0,497	0,233
IM_total	0,071	0,144	0,109	0,102	0,781	0,806	0,430	0,714	0,720	0,955	0,803	0,610	0,693	0,717	0,998

* / ** / ***: 90% / 95% / 99% confidence level. P -values are within brackets, R^2 is the (adjusted) coefficient of determination, AIC the Akaike Information Criterion, N the number of observations. Null of RESET p -value: correct and robust specified conditional mean of the dependent variable. Null of IM-test p -value: joint homoscedasticity and normality of the errors (Long and Trivedi, 1992). Variables are estimated with robust clustered standard errors, but not the IM-test statistics as STATA 12 does not provide these with clustered errors.

unanimity among policymakers for decreasing the EU ETS cap. Indeed, in October, 2006, the European Commission announced stricter NAPs for Phase II. This might explain why the abnormal returns were negative, even though lower carbon prices should be conceived as good news for cost-effectively achieving emission targets.

Over the event windows, *carbintens*, *tradeintens*, *exp*, and *borrow* had a significant impact on the *CARs*. The variable of *carbintens* shows up in two full model regressions, *exp* in one, and *borrow* and *tradeintens* in none of them.

The coefficient on *carbintens* is negative, indicating that the carbon price drop has a more negative impact on share prices of dirtier firms. For example, for event window t_2 , if a firm's *carbintens* increased by one standard deviation, this would lead to an average *CAR*-decrease of -0,41%. Relative to the *CAR*-average of -0,8% for this window, this is quite substantial. That investors value carbon-intensity negatively is a sign that the EU ETS is valued as restricting pollution. Firms are considered more profitable with lower carbon-intensity rates as these signal towards better abatement capacities. This finding is in line with Koch and Bassen (2013) and runs counter to Oestreich and Tsiakas (2012) who concluded that investors demand a higher carbon risk premium for the (expected higher) cost of capital of dirtier firms.

The insignificance of *carbleak* leads to a rejection of Hypotheses H.1 and H.2. The descriptive statistics (cf. Section 5.3) showed that only sector 1 (Power & Heat) and sector 3 (Cement & Lime) provide support for H.1 and H.2, while the support of the six other sectors was the opposite. There can be several reasons for these incompatible findings. For one thing, the variable *carbleak* may not have sufficient detail. Unknown is the actual carbon pass-through rate by firms. It is further probable that this cost pass-through threshold, for which

market value impacts turn positive, does not lie at/above 100% but at lower rates. Further research is necessary to find this out.

The second variable, *exp*, is only significant in t_1 . The positive estimate of *exp* indicates that the carbon price drop led to larger share price increases for firms which were more ‘long’ or less ‘short’ on allowances. Increasing *exp* by 10% translates into an average CAR impact of 0,013%. Since the full sample average of event window t_1 equals -0,3% its impact is small. That *exp* is positively related with the CARs is in contrast with Hypothesis H.3. This positive *exp*-to-CARs relationship is in line with Abrell et al. (2011) that over-allocated firms were more profitable, the latter of which should correspond to higher share prices.

The impact on CARs from trade, or *tradeintens* and *notrade*, is absent in the full model regressions. It is likely that *carbintens* and/or *exp* captured the variance from the CARs instead. This can also explain why *borrow* is insignificant, since the only difference in the definitions of *exp* and *borrow* is the net sales in allowances. There is thus no evidence that investors valued the firms’ net sales of allowances, or that value is derived from the being a large trader, irrespective of them being buyers or sellers. Hence, both Hypothesis H.4 and H.5 need to be rejected.

In one respect it is surprising that the trade variables do not come up in the regressions. As listed firms normally manage their currency exposure, it is probable they do that for their carbon exposure as well. And as the carbon market was relatively new and carbon prices were high, market traders could have engaged in profitable trading strategies. Although they may have done so, it had no discernible effect on share prices. Nevertheless, it is also not surprising this carbon trade effect is missing. Few measures are available for investors to gauge a firm’s trade activity. Data on forwards and futures positions taken is not

publicly available. Besides, the EUTL data is published 5 years after an EU ETS calendar year. In some U.S. emissions trading schemes data on emissions is published daily and annually on the allowances transferred. While continuous monitoring of greenhouse gases may be expensive (at least for now), there should be no technical limits on more frequent publications of the transfer of allowances. Without a view on the trade in allowances, one cannot discern whether firms e.g. borrowed or stockpiled unused allowances. This information shortage constrains markets in realizing their valuable allocation properties.

Another information constraint results from the compliance timing as laid out in the EU ETS Directives. While (currently) allowance auctions are spread over the calendar year and thus ensure a gradual feed-in of information, there is just one moment in the year that all firms surrender their allowances. It will be conducive to market certainty if there are more of such moments during the year (e.g. Holland and Moore, 2012) and that the European Commission subsequently reports on these compliance moments.²⁷ This would have prevented or at least reduced the April 2006 shock. The more that signals on scarcity are held up, the more difficult it becomes for firms to forecast whether they have planned enough emission-reduction projects. If the release of information on the scarcity in the EU ETS is stepped up, situations of over-allocation such as the EU ETS faces currently are more likely to be averted.

6. Conclusion

Did EU ETS firms' shareholders interpret the April 2006 carbon price drop as significant and, if so, how did the event's impact differ among firms' allocations and transactions? Through an event study the cumulative abnormal returns (*CARs*), i.e. the event-induced share price returns, were derived from a sample of exchange-listed firms participating in the EU

ETS. The *CARs* statistics indicate that shareholders interpreted the event as having negative value-relevance. In that sense, the EU ETS did ‘bite’.

For the share price responsiveness to the EU ETS three groups of variables were checked: 1) the product’s carbon-intensity and carbon leakage, 2) the short and medium-term allowance holdings, and 3) the trade in allowances. The results indicate that the product’s carbon-intensity and medium-term allowance holdings were, respectively, negatively and positively related to the firms’ share prices. As to the medium-term allowance holdings, we expected that the carbon price drop would increase the profits for firms having allowances shortages, *et vice versa*. Since we found opposite results, the market possibly incorporates a longer time horizon than expected. With future expected stringency of the EU ETS, firms are considered more competitive with lower carbon-intensity rates and larger allowance holdings as both are signals of better abatement capacities. The EU ETS is thus valued as a restriction on pollution.

Finally, the firms’ trade activity in allowances was not value-relevant. This result may well be the consequence of investors lacking sufficient data on the firms’ allowance trade. A valuation will then be difficult to make when it is not known whether firms e.g. borrowed or stockpiled unused allowances. The market will therefore benefit if the European Commission increases the frequency of publications of the emissions of firms and their allowance transfers.

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² Due to space constraints, we refer the reader to Böhringer (2014) for a recent, more general overview on EU ETS developments.

³ There are more event studies on the EU ETS, e.g. Mansanet-Bataller and Pardo (2007).

⁴ This relationship holds with grandfathered allowances. With auctioning the effect on market values is neutral. Allowance costs are then not only an opportunity cost but an out-of-pocket expense as well.

⁵ Regulatory changes are often gradual and expected. Event study estimates will then become biased if key dates in the regulatory process are ambiguous. However, the information on the excess amount of allowances came as a shock to the market (see e.g. Figures 1 and 2). Moreover, in the April 21st 2006 edition of *Carbon Market Europe* of Point Carbon, it was argued that the CO₂ price was too low (Ellerman and Buchner, 2008). The expectations before the event thus indicate a CO₂ price movement in the opposite direction.

⁶ In the calculation of the Return Index, dividends or share splits are corrected for.

⁷ The disclosure of emissions by EU Member States did not take place on the same day. The shock can thus be more pronounced for firms from the countries that were first at disclosing their national demand for allowances.

⁸ Bushnell et al. (2013) take the 26th until the 28th of April as the event window. They stated that little information had leaked into the market and that, otherwise, the carbon price would have responded to that. However, as Figure 1 shows, the carbon price fall had already started between the 24th and 25th.

⁹ Five days in between the estimation and event window is allowed for to prevent events affecting the event window.

¹⁰ The Orbis database does not provide the percentage of revenues attributable to a firm's installation(s). Firms having relatively more installations outside the EU ETS thus seem to have 'clean' output. Their lower exposure indeed enables them to switch production to the non-EU ETS installations.

¹¹ For several firms, we relied on revenue data from Datastream in case Orbis was not able to provide it.

¹² As the NAPs predetermined most of the allocations for Phase I it should pose less of a problem to assume that emissions for 2006 equal those of 2005.

¹³ This trade data, i.e. from the EUTL registry transactions, is published five years after an EU ETS calendar year. Investors thus did not have it at their disposal during or before the event. In this analysis it thus functions as a trade proxy. Investors should have obtained their allowance trading estimates via other information sources.

¹⁴ As mentioned in Section 4.3, it could not be discerned whether the allowances received from or surrendered to the national registries were part of 2005 or 2006 tranches. Some installations received allowances more than twice, suggesting these were corrections rather than allocations. We thus opted for the verified emissions to be included in the analysis.

¹⁵ An overview of the NACE industries, its EU ETS sectors and carbon leakage categorization is available on request.

¹⁶ For cases where the NACE industry text descriptions closely resembled those of the carbon leakage descriptions, we allocated them to the carbon leakage list.

¹⁷ This ETS sector categorization is used in more studies, among others in Ellerman and Joskow (2008).

¹⁸ More than half of firms are in sector 8, the residual category. Relatively few firms within sectors 1 to 7 were publicly listed. And if we relied on primary or secondary NACE codes instead of core codes, some companies are active in more sectors.

¹⁹ We leave sectors 6 and 7 out of the discussion due to the small number of observations.

²⁰ The net effect consists of firms with a positive and a negative event effect. The negative effect amounts to € -109,5 billion and the positive effect to € 55.6 billion.

²¹ We assume firms used (most) of their 2005 allocations to cover their 2005 emissions. The opportunity costs of holding allowances will then relate to the 2006 allocation but also the 2007 one, from which firms can borrow for their 2006 emissions.

²² Table III and Table IV below provide these statistics on different numbers of firms. Of the total amount of 393 firms, 16 firms had zero allocations so that *exp* and *borrow* could not be determined; 27 firms had zero emissions so that *carbintens* and *carbileak* could not be determined.

²³ Relative to their purchases and sales, their allocations and emissions were very small. The outlier statistics did not detect these three firms as outliers, so they were included in the analysis.

²⁴ To detect outliers, the deviation of the residual, the leverage and influence of the observation were considered (Baum, 2006: section 5.2.10). Nature Group PLC and Providence Resources PLC were consistently detected and therefore left out of the analysis.

²⁵ We performed several robustness checks. More information is available on request. Concerning endogeneity, we expect it to be minor. The abnormal returns (i.e. changes in the firms' expected profitability) as well as the independent variables are in relative rather than absolute terms. During the small event window, unobserved heterogeneous factors from the error term (e.g. productivity levels) are therefore unlikely to have changed and thereby impacted the abnormal returns via the covariates. Furthermore, the event was not anticipated (cf. endnote 5) and it was not induced by firms themselves, but by the EU Member States release of emissions information.

²⁶ We use robust clustered standard errors based on the eight industry sectors.

²⁷ While Holland and Moore (2012) is on the Los Angeles NO_x market, it may be applicable to (non-point) CO₂ emissions as well.